Burnett (S. M.)

ARE THERE SEPARATE CENTRES FOR LIGHT-, FORM-, AND COLOR-PERCEPTION?

Compliments of
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ARE THERE SEPARATE CENTRES FOR LIGHT-, FORM-, AND COLOR-PERCEPTION?

By SWAN M. BURNETT, M.D.,

WASHINGTON.

THAT knowledge of the external world, which comes to us through the medium of the organs of vision, has been broadly divided into three classes: 1, the perception of light or the sense of illumination; 2, the sense of form; and 3, the sense of color.

As the phenomena of each of these classes have pretty clearly circumscribed limits, and can, under ordinary circumstances, be sharply differentiated from each other, they have gradually come to be looked upon in some quarters, as distinct senses; correlated, perhaps, but still essentially independent of each other.

The first to distinctly put forth the idea of a separate existence of white light was Hering, in his theory of the perception of colors. As is well known, this theory rests on the supposed antagonistic action of red and green, and blue and yellow light, and of white light and its opposite, black, on three distinct chemical elements supposed to exist in the retina. Later, Steffan and others embraced the idea, and very recently the views in regard to the separate cerebral centres for each have been formulated and put forth systematically in a brochure by Dr. Hermann Wilbrand.[1]

[1] "Ophthalmatrische Beiträge zur Diagnostik der Hirnkrankheiten," Weisbaden, J. F. Bergmann, 1884, p. 100.

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In this monograph the ground is taken that there are three separate and distinct centres in the brain for the perception of light, form, and color. His theory is ingeniously defended by cleverly constructed diagrams, and an appeal to clinical facts. It has received wide attention among ophthalmologists, and will, probably, on account of its plausibility, meet with an acceptance more or less general. On this account, it has seemed to us important to examine somewhat into its merits, and to see how far it is in consonance with the principles of positive science and clinical observation—for, an acceptable theory on any question involving physics and physiology, must satisfy the demands of both.

It is sought, by this theory, to explain certain phenomena of abnormal vision which have been found associated with affections of the brain. These phenomena are: 1, The absence of the perception of color, the senses of form, and light being intact; 2, the absence of color- and form-perception, the sense of illumination being left; 3, the total abolition of the sense of vision when light-perception is destroyed.

In an attempt to explain these clinical manifestations, the following facts are to be remembered, stating them in an inverse order to the above: 1, that the sense of light is never lost without a concomitant disappearance of the senses of form and color; 2, there is never a loss of the sense of form without an associated loss of the sense of color—with an apparent exception which we shall notice later; 3, the sense of color may be lost, while the senses of form and light are intact.

Wilbrand attempts to explain these facts in the following manner: As the sense of color may be lost while the senses of form and light still remain, he argues that there must be a centre somewhere which presides over this sense, and that this centre must have an independent connection with

the retina. For the same reason, the sense of form must also have an independent centre with a connection with the retina, independent of that of the centre for light and color; and, similarly, there must be an independent centre with a separate connection for light-perception.

That is all simple and plausible enough, but in order to explain the facts of the unvarying succession of phenomena as described in the preceding paragraph, it has seemed to him necessary to assume a certain connection between the three fibres connecting the centres with the retina. As the sense of light is never lost without carrying with it a loss of the other senses, it is assumed that there is a fibre going from the retina to the cerebral centre which is common to all three, and as it is supposed that the sense of light comes first in the order of centres, an abolition of this centre must necessarily mean an abolition of the other senses, since all the centres are thus cut off from their connection with the retina. When, however, the centre for color alone is destroyed, or hindered in its function, the connection at the centres of form and light are left intact and these senses are unimpaired. When the centre for form is destroyed, the centre for color being cut off from its connection with the retina, its function is also destroyed, and the centre for light alone remains unimpaired.

But in addition to this fibre common to all three centres the centre for form has one which connects it with the centre for light and the retina, and the centre for light has one which connects it independently with the retina. As a result of this arrangement each separate cell in the centre for color has a single fibre bringing it in communication with the retina, which it shares in common with the centres for form and light; the centre for form has two, one in common with the centre for light and color and one in common with the centre for light alone; the centre for light

three, one in common with the centres for form and color, one in common with that for form, and one direct and independent of the other centres. From every percipient point in the retina, therefore, there go three separate fibres to the centre of vision in the brain: one to the centre for light, one to that for form, and one to that for color, with the connections above stated.

Into Dr. Wilbrand's scheme there enters an arrangement of the fibres and cerebral cells with reference to the different parts of the retina; but we shall have nothing to do in this paper with any points unconnected with the idea of three separate centres for light, form, and color.

It cannot be denied that this is an arrangement by which it is *possible* to explain the phenomena in question, but it is certainly not in the spirit of modern science to accept such an explanation without some proof, either positive or analogical, on which to base it. The proof in question can only be found in the application of the laws of wave motion as manifested in the domain of molecular physics, in experimental physiology, and demonstrated pathology. Such proof is as yet wanting. The whole scheme is a figment of the imagination, and is furthermore a species of speculation which, if allowed to become common in ophthalmology, will tend to depose it from the high stand it has taken as the most nearly positive part of the science of medicine. It shows, also, to what lengths we may be led when once we lose our hold on the positive data of science, and no longer rest on the basis of fundamental principles.

So far as the physical part of vision is concerned we know that it has to do with wave motion of ether, and the action of this on the ultimate particles of the matter of which the organ of vision is composed. We can afford here to leave undecided the question of the existence, or not, of fibres going from the retina to the brain. No such continuous

structures have yet been demonstrated, but the possibility of a single fibre connecting an ultimate molecule of the retina with one in the brain will not perhaps be denied. It would, however, very much simplify a study of the case if we referred the whole matter to the action of wave motion on a homogeneous structure. If we are to accept Wilbrand's scheme, however, we have *three* distinct fibres connecting every *recipient* element at the retina with every *percipient* element in the brain. That would make sufficiently large draughts upon the physical capabilities of the structures involved, but they are doubly increased if we add the three fibres for the three fundamental colors, as demanded by the Young-Helmholtz theory, making *six* fibres from every element of the retina to every element in the brain.

Such fibres, as every one knows, have not been demonstrated, but it does not seem to have occurred to investigators to question the necessity of their existence, and to seek an explanation more in keeping with the demonstrated laws of wave motion as applied to homogeneous molecular structures. We have endeavored in another place[1] to bring these laws to bear on the elucidation of the question of color-perception.

There is nothing so delicately elective as wave motion in a structure whose molecules are properly adapted in their arrangement to this display of its powers. In such a structure any number of different vibrations will pick their way safely and without the least interference with one another, through long distances.[2] No one, we presume, will contend for a separate fibre in the small wire of the telephone for every distinct note which goes to make up the human voice in speech, and yet the retina and optic nerve, which are highly organized structures, have not more required of

[1] "Theories of Color-perception," *Amer. Jour. Med. Sci.*, July, 1884.

[2] Of course it is not contended that these wave motions are transmitted singly as such, but every variation in wave motion is felt in the resultant effect.

them in this particular than the inorganic and (so far as we know) homogeneous substances of which the telephone is made. We have in the organ of vision molecular structures acted on by wave motion, why then, in explanation of the phenomena resulting from this action, should we go beyond the laws which have been clearly demonstrated to apply to similar phenomena in the inorganic world?

When we come to consider the question of three separate centres in the brain, we have passed, it is true, the bounds of physical science, and have to deal with a physiological function and a psychical phenonenon, but even here, we cannot in our attempts to form a theory legitimately go outside the laws which have been found to govern like phenomena.

Let us reduce the physiological and psychical phenomena of vision to their simplest terms. What are light, color, and form? The difficulty with those treating of the subject heretofore has been, it seems to us, that they have not been able to free their minds from the metaphysical system of thought. The words, light, color, and form, are regarded as *entities*, and as having existences in fact, and to be accounted for as such. It is strange that we should have this remnant of the old school of thought engrafted on the positive system of modern science, and ophthalmology is not the only department of thought that has felt its ill-effects.

The phenomena of vision are but the interpretations of impressions made on the retina and carried thence by means of the optic nerves to the brain. Light is only the translation of wave motion into sensation.[1] How this is effected

[1] Plato defined light to be "the power that through the eye manifests color." The same idea (which is the true one), is also expressed by Ruskin in his own inimitable way in one of his latest utterances ("The Storm-cloud of the 19th Century," two lectures delivered at the London Institution, 1884). "Light and sound are *sensations* of the animal frame which remain and must remain wholly inexplicable, whatever manner of force, pulse or palpitation may be instrumental in producing them; nor does any such force *become* light or sound

we do not know. But we do know that when waves of ether of all the lengths which are capable of being perceived act at one and the same time, we have a sensation called *white;* when a limited number or a single wave acts, the sensation is known as *colored.* We know further, *that there is no white light sensation that cannot be resolved into its constituent elements of color-sensation.* In the language of physics, there is no white light that cannot be broken up by the prism into the spectral colors.

White and color, then, being expressions of the effects of wave motion, differing only in degree, cannot be looked upon as distinct sensations. *Moreover, since the whole must comprehend all its parts, white light must include all colored light.*

To suppose a separate cerebral centre for the two, therefore, seems to us about on a par with the proceeding of the philosopher who cut a large hole in his door to admit the cat and a number of smaller holes to admit the kittens.

The sense of form, as far as it pertains to the organ of vision, is but the expression of the idea of extension as represented by the amount and form of the area of the retina impressed. But to call the idea of form a purely visual sensation is erroneous. It is an expression of the judgment which is based on information received by the brain from other sources besides the eye.

The impression received from the retina must be verified by that given by touch before a correct idea of form can be entertained. Long experience has enabled us to supply from memory this second factor, and in ordinary vision, our judgments are formed from the retinal impressions alone, but it is only a process of education which enables us to do it.

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except in its recontre with an animal. The leaf hears no murmur in the wind to which it waves on the branches, nor can the clay discern the vibration by which it is thrilled into a ruby."

To use again the terms employed in physics, light (comprehending color) is a *qualitative* sensation, form a *quantitative* sensation. Light and color are the judgments formed on the basis of the character and number of the ethereal undulations ; form is the idea based on the extent of the retina affected, together with the knowledge previously or concomitantly obtained through the muscular sense and the sense of touch. As has been stated before these ideas are only the translations of impressions carried to the brain—but is it necessary that there should be a separate centre for their perception ? As these ideas are but states of consciousness we would have as much right to suppose a centre for every one of the other million states of consciousness that happen daily in our lives.

In order to avoid a labyrinth of complications we must assume that there is an overruling power of judgment, which takes cognizance of all impressions received, which combines and discriminates, and finally leads to the condition we denominate consciousness. That there is a certain portion of the brain set apart for the reception of particular kinds of impressions is a plausible induction, and is support by many facts in experimental physiology and in pathology. Thus, it is almost certain that there is a particular part of the cortical substance of the posterior cerebral lobe which is intimately connected with the sense of vision, for when it is destroyed the power of seeing is lost. Such a centre will suffice for the reception of all impressions made on the retina, but when we seek to explain how these impressions are interpreted by the faculties of the mind we pass the boundary of physics and physiology, and enter a region concerning the essential nature of which we are in absolute ignorance.

Up to this point, however, we can legitimately go with our wave motion and molecules, in an attempt to account for the phenomena.

Making an application of these laws of wave motion, then, can we consistently explain the three conventional divisions of the visual function—viz: light-, color-, and form-perception—on the basis of one cerebral centre for all? From our point of view, the task is not at all a difficult one. We have already noted the physical impossibility of separating white and colored light on account of the demonstrated fact that white light includes the colors, and that there is no colored light which is not contained, potentially, in the white.

We will assume, for the sake of illustration, that each individual element in the retina has a corresponding element in the cerebral centre, with which it is connected by a single fibre. When one of these retinal elements vibrates in a certain phase, which is set up, we will say, by the ethereal undulation corresponding to the sensation of red; this vibration is conveyed to the cerebral centre, and the corresponding cerebral cell vibrates in the same phase—resultant sensation, red. The same retinal element vibrates to the phase green—which vibration is repeated in the cerebral element—resultant sensation, green. The retinal element vibrates with the ether wave, producing blue; this, repeated in the cerebral cell, gives rise to the sensation of that color; and so on for yellow and all the other distinguishable colors. Let these ether waves, and all the others corresponding to the colors in the solar spectrum fall upon the element at the same time, and the *resultant* vibration phase (according to well-demonstrated laws of physics) will be different from any, and all combinations short of the whole as they differ from each other; this vibration phase, carried to the brain, is reproduced by the cerebral element; resultant sensation, white.

This explanation is simple, in strict accordance with the known laws of the physics involved, and thus fulfills all the requirements of an acceptable working hypothesis.

The idea of form, so far as it comes from the eye, is simply explained by the sensation resulting from the *number* of the cerebral elements (corresponding to the number of retinal elements impressed) affected, and their relations to each other in space.

We have, therefore, in this scheme, but one set of cerebral elements corresponding to the retinal elements on which the impressions are primarily made.

We have not time nor space to enter into an elaboration of this hypothesis in explanation of all the various phenomena of normal and disordered vision. We shall only notice a few manifestations which the scheme of Wilbrand was constructed to explain. These phenomena, as we have noted at the beginning of this article, are the absence of color-sensation (generally in one half of the retina), the sense of form and light being intact, and the presence of the sense of light when both color- and form-sensation are absent. These phenomena are accounted for by W. on the supposition of a destruction in the first instance of the centre for colors, leaving the other two centres unharmed; and, in the second instance, by a destruction of the centres for both color and form, that for light remaining intact.

Cases of hemi-achromatopsia, or defective color-sense in corresponding halves of each retina, are not uncommon. The defect may be partial or complete—that is, some of the colors may still be properly perceived, or it may be impossible to recognize any. Wilbrand gives the clinical histories of six such cases in more or less detail, and the histories of two other cases of "amnestische Farbenblindheit," in which there existed a want of power to express in words correctly the color sensations. Several other cases have been reported which are not in W.'s list,[1] and among them one by Dr. Eperon in the *Archives d'Ophthalmologie*, for July and

[1] Shoeler reports eight (*Beit. z. Path. d. Shenerv.* 1884), and Noyes two (*Arch. of Oph.*, vol. XI.).

Aug., 1884, which is of especial interest on account of the very careful and complete examination to which the patient was subjected, and on account of a peculiar derangement of other cerebral functions. In all these cases there was a diminished or abolished chromatic sense alone, or combined with loss of form sense, while the sense of illumination remained. This fact in reference to these cases, is to be noted, however, that in none of them, except that of Eperon, was any photometric examination made. Eperon found, in his case, the sense of illumination reduced to $\frac{1}{3}$, and until such examination in other cases reveals a perfectly normal sense of illumination, we cannot accept it as a fact that in complete hemi-achromatopsia there is no diminution of the light-sense. On the other hand, in some of the cases, it is distinctly stated that it is reduced.

In congenital, so-called, color-blindness we have, as a rule, normal visual acuteness, but it is to be remembered that here we are undoubtedly dealing with errors of judgment and not with a pathological condition of the nerve centres.

When there is a pathological alteration in the cerebral centres, its effect must be felt on its molecular structure—in fact, that is the essence of pathological change. The effect of a pathological change in the molecular structure at the centre for vision would, most naturally, be an impairment of the power of the molecules to respond promptly and readily to the wave motions corresponding to the different colors. It is readily understood how delicately organized must be the molecular structure in order that it respond to such very slight variations in wave motion, and how easy it would be to throw it out of its equilibrium. It can also be easily understood how this change in molecular structure might be such as to prevent it from responding to certain wave lengths, while it would be affected by the force of the vibration movement of the whole spectrum acting at once.

On this simple conception is it possible to explain all the phenomena of hemi-achromatopsia that have, as yet, been observed. Moreover, we have a parallel condition in affections of the choroid and retina in which the retinal structure is no longer normal in its molecular arrangements. In a case of extensive choroidal changes which I recently examined there was perception of light over the whole of the visual field, and in the outer, lower and part of the upper inner field there was color-perception which did not depart very markedly from the normal, but in the lower inner field there was no distinguishing of colors. And with this loss of color-perception there was associated in this part of the field a diminution of the sense of illumination. The white square of the perimeter appeared to her to be much "brighter" in the outer and upper and inner field than in that portion where there was absence of color-sensation. In another case of extensive choroidal disease where the visual power was reduced to counting fingers at two feet, there was an irregularly concentric contraction of the field for white. In this field no colors were distinguished except red, which, however, had a "pinkish tinge," and was only recognized in the outer field near the point of fixation. In both these cases the fellow eye was normal. We, therefore, do not believe that there can be an absence of color-perception from pathological causes without a concomitant lowering of the sense of illumination of a greater or less degree. We can conceive it possible, however, that the molecular disturbance may be so slight as to affect perceptibly one or two undulation phases only, the others remaining unaffected. Under these circumstances the sense of illumination might not be much lowered and form-perception intact.

In reference to Eperon's case, it should be remarked in addition, that there was an impairment of judgment in respect to the memory and power of reproducing words

that had been *read*, though those that had been *heard* were more easily repeated. How far this change had affected the judgment of color impressions we have no means of knowing, but it must nevertheless remain a possible factor in the case.

It is a clinical fact, brought out clearly in the cases collected by Wilbrand and others, that when the sense of form is lost the sense of colors is lost also, though the sense of light may remain. No case has yet been reported where the sense of form has been lost while that of light and color remained. Wilbrand accounts for this by supposing that the color fibre going from the retina to the brain passes through the centres for white and form before reaching the centre for color. Therefore, a destruction of the form-centre, must, by cutting off the connection between retina and color-centre, necessarily involve a loss of color-perception.

The concomitant loss of form- and color-perception is much more simply accounted for on the principle of variation in molecular motion. A moderate amount of change would so alter the responsive power of the molecules that they could not act promptly to the waves of the different colors, but yet their position and relation to each other may remain nearly or quite normal, so that when they *are* affected by all vibrations of the spectrum at once the resultant sensation will be projected nearly or quite in a normal manner. When, however, the change is so great as to displace the molecules from their normal position, but not entirely to annul their vibrating power, the vibrations still give rise to a sensation, but the position of the vibrating molecules in their relations to each other is so altered from the normal that they cannot be properly projected by the consciousness, and so no distinct image is perceived, though there may be a general sense of illumina-

tion. The condition has its analogue in opacities of the cornea through which ethereal undulations may still pass; but the rays are so scattered that no image can be formed. In order to have a definite sense of form a certain number of molecules in a definite order must be affected. When the sense of illumination is retained under these circumstances it will most likely be reduced very much in power—and no cases have been recorded in which it approached the normal.

In connection with this part of the subject there is a very remarkable statement on pp. 23-24 of Wilbrand's brochure. He says: "A separate irritation of the color-centre, as a physiological experiment, without a participation on the part of the form and light sense, has not yet been demonstrated, but the bright red color sensation we experience when looking toward the sun with the eye-lids closed is explained by a simultaneous excitation of the light and color centres to the exclusion of the form centre. Leber says (Gräfe u. Sæmisch. v. 1042): 'we see not colors but colored pictures, the form element cannot be separated from color-perception and the centre of both must be the same,' but the two above mentioned cases and the experiment with the closed lids show that there must be the clearly defined centre for form and color, though ordinarily in every picture formation all three centres are affected."

It is hard to believe that scientific men are serious when they adduce such opinions in support of an hypothesis for which they claim attention. I would ask these gentlemen how we are to experience the sensation of a form when there is no image pictured on the retina? In the experiment alluded to, light passes through the partially translucent tissues of the lids and reaches the retina—but the rays are so irregularly diffracted from their course that no distinct image can be formed, and there is only a diffuse lumi-

nosity, the same as when light passes through frosted glass. Its red color is of course due to the blood in the tissues through which it passes. But to say that under these circumstances we can have no sense of *space* is not true, for when the experiment is made with a candle the position of the candle in the visual field can easily be recognized because there is always one part of the retina where the luminosity is most intense, and this is properly projected. It is to be borne in mind in this connection that the sense of form is only a more refined or highly developed sense of projection.

We would call attention at this place to another physiological experiment which, it seems to us, will be difficult to explain on the three-centres theory. We allude to the so-called after-images or the residual sensations of white light. When white light, either direct from the sun, or reflected from as nearly a white surface as we can find, is thrown into the eyes for a few seconds, and the lids are then closed and the hands placed over them so as to exclude all extraneous light, the after-image undergoes a series of changes in *colors*, beginning usually with blue and ending with red. In some of the hundreds of these experiments that I have made, I have noted as many as seven different colors and shades; but *never* after the eye is closed has there been a sensation of white. Have we here a sensation of color independent of white light? Certainly not. Even if Newton had never made his immortal discovery, this simple experiment would be sufficient to establish the compound nature of white light, and it removes beyond the pale of controversy the question of the composite character of the sensation of white.

If white light is a distinct sensation, and has a centre of its own, its after-images should be not colored, but shades of gray, because, in Wilbrand's scheme, while a color-sensa-

tion may include white, the converse is not true, and white does not, of necessity, include colors.

The phenomena in question are easily explained by the theory of the action of wave motion on molecules. White light, holding all the undulations corresponding to all the perceivable colors falls upon the retina and the vibrations are carried to the visual centre. These vibrations vary in intensity and amplitude, according to their corresponding colors, but when they all act *at once*, the sensation is white.[1] When the eye is closed, however, and the retina is cut off from the source of illumination, the vibrations already set up in the visual apparatus still continue in accordance with the law of inertia; but soon some of them stop and then there is a destruction of the equilibrium of the color-forces, the stronger come to the fore, and there is no longer a resultant sensation of white, but of the predominant color or colors. We have not time to examine here into the reason why blue should be the first color to manifest itself, but it is probably due to the fact that, the blue waves being more rapid, act more quickly and forcibly at the beginning, but are, on the other hand, soon exhausted, while the red, though less active, being stronger and having greater momentum, last the longer.

To sum up, then, we do not think the existence of three cerebral centres for the separate perception of form, color, and white has been proven by either anatomical investigation, physiological experiment, or the manifestations of pathological change. Moreover, we fail to see the necessity for their existence, since all the phenomena of normal and disordered vision can be easily and consistently accounted for on the well-known and abundantly demonstrated laws of wave motion in the domain of molecular physics. In accordance with these laws, one cerebral centre is all that is

[1] The so-called color-blind, who sees all colors as modifications of two, calls the sum of all his color-sensation *white*.

necessary. Its molecular structure is in a condition of delicate equilibrium, which allows it to answer promptly to all the vibrations which come to it from the retina—embracing all those which answer to the colors in the visible spectrum. It is able to respond in phases peculiar to any one color, or to any combination of colors, when the resultant sensation will be of *color*. When the phase of vibration answers to all the undulations embraced in the solar spectrum, the resultant sensation will be *white*.

By a process of education we have learned to project the impressions coming from a certain part of the retina (and affecting, probably, a certain part of the visual centre) to a certain position in space. When these projections have a definite outline we have a sense of *form*.

Unless some phenomena present themselves which cannot be accounted for on this theory, we contend that we must, as scientific physiologists, accept it as a working hypothesis until there arise discoveries in the laws of the action of wave motion on molecules with which it is inconsistent. Moreover, we hold it to be dangerous to scientific advancement and truth to promulgate speculations which have not their bases in these fundamental principles.